Overcoming Roadblocks Facing the Implementation of Innovations: Three Case Studies at Caltrans

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ABSTRACT

This paper examines Caltrans experience in three recent showcase innovations developed at Caltrans Division of Research and Innovation. Although these innovations promised significant return on investment, deployment faced significant challenges, which motivated the undertaking of this research. For each case, professionals were interviewed to analyze roadblocks encountered. Lessons learned and mitigation measures that were successful in each case are presented.

The first case is Sensys™, a compact, low cost wireless traffic sensing system that can replace less reliable, more expensive inductive loops. The second is CA4PRS, a software that simulates highway construction, predicting traffic delays associated with simulation scenarios, to optimize construction quality, costs and traffic impacts. The third, Balsi Beam, is a mobile frame designed to protect highway workers.

Findings show that deployment faced roadblocks because: 1) transportation projects are complex, multifaceted, inter-jurisdictional with many players having different interests; 2) multiple layers of decision making sometimes lacking logic; 3) public sector procurement driven by competitive multiple low-bid processes often infringes on intellectual property rights; 4) public agencies resist change, and 5) risk aversive executives hesitate to implement new innovations.

To mitigate roadblocks, this paper advocates following a systems engineering process that ensures the inclusion of customers throughout all phases and ensures that the final product meets their needs and satisfies their requirements. Findings underline the need to interconnect researchers, developers, operators, and decision makers by improving communications at all levels and stages. Findings emphasize utilizing innovation champions. Findings showed the need for timely establishment of criteria for evaluating new innovations.

BACKGROUND

Transportation Innovation in the 21st Century:

In the transportation world of the 21st century, many challenges are created by inadequate resources needed to address today's massive transportation problems of congestion, failing infrastructure and environmental impacts of transportation, most notably worsening air quality and climate change. Innovation should, and can lead to improving the performance, efficiency, and quality of transportation system as well as reducing their environmental impacts. Innovation is much needed to manage the enormity and complexity of transportation system. As noted in the TRB Special Report 261, "complexity of the transportation challenges underscores the need for new ways of looking at problems and for innovative solutions, offering significant research opportunities in all facets of the highway sector" (**1**).

However, due to its large and fragmented customer-base, transportation seems to be a very difficult area in which to produce innovation. Whether the innovation is incremental, partial, complete, radical, smooth, or disruptive, the new system, product or process will have to overcome major hurdles of becoming accepted as the new way of doing business. The different types of innovation face different obstacles, but the more radical or disruptive an innovation is, the more challenges accompany its acceptance and implementation.

Research Motivation:

This research was largely motivated by desire of the authors to share lessons learned in the three major cases of implementation of innovation by Caltrans in California. Moreover, there is hardly any literature describing real-world innovation case studies, especially in recent years, such as those described in this paper. The 3 cases taken together cover a wide spectrum of barriers in encountered in new transportation technologies. The first innovation, Sensys™, is a revolutionary traffic sensing innovation that combines latest communications at roads and highways and had to be implemented in an evolutionary manner. The second, Balsi Beam, is a revolutionary safety hardware innovation that needed revolutionary approach to implementation. The third, CA4PRS, is an evolutionary strategic and tactical planning and control software innovation that is being implemented in an evolutionary fashion.

What is Innovation?

In defining innovation, we distinguished the subtle difference between an "invention" and "innovation." According to Merriam-Webster On-Line Dictionary, invention is "a device, contrivance, or process originated after study and experiment" **(2).** However, the same source defines innovation as "the *introduction* (emphasis is ours) of something new, a new idea, method, or device."

Utterbeck (**3**) described three stages of innovation in developing a successful industry. The first is "product design and innovation." The second stage is when "resulting innovation begins to become dominant and firms with ability to manufacture [with] quality [will] more efficiently dominate [the market]. In the final stage, those firms that can compete based on the economies of scale and capital intensity dominate industry" (**3**). The 2001 Transportation Research Board (TRB) Special Report 261 emphasized the need to tie innovation to "improving performance, cost-effectiveness, quality, or safety, or reducing environmental consequences" (**1**).

As such, an innovation, whether a new idea, method, or device, is incomplete unless it is made part of a working system. Thus, we see innovation as the introduction of something new and deployable. In this paper, we define innovation as the creation AND successful implementation of a new useful product that becomes widely used by the transportation industry.

Types of Innovation

Luecke and Katz (**4**) identified three different types of innovation: incremental (evolutionary), radical (breakthrough), and disruptive (revolutionary) {text in parenthesis is ours}. "Incremental innovation is generally understood to exploit existing forms or technologies" (**4**). This type of innovation is appropriate for improving the organization's current processes and products to capture more of the market share. On the other hand, radical innovation is "something new to the world, and a departure from existing technology or methods" (**4**). The terms *breakthrough innovation* and *discontinuous innovation* are often used as synonyms for radical innovation. Lastly, disruptive technology is used "to describe a technical innovation that has the potential to upset the organization's or the industry's existing business model" (**4**).

There are varying perspectives on which innovation approach is most desirable in transportation. In a recent survey of transportation professionals, 73% of academic respondents believed the focus should be on revolutionary innovation whereas only 27% of non-academicians believed so (scheduled 2009 TRB presentation). AlKadri, Benouar, and Tsao argued that the implementation of even revolutionary transportation innovations, such as the Automated Highway Systems (AHS), needs to take place in a modular and incremental manner (**5**). They argued that immediate implementation of a fully automated highway system may not be feasible or desirable because it does not allow for the necessary testing and evolution of technology, markets, and social change.

COMMON BARRIERS TO INNOVATION

Whether the innovation is incremental, radical, or disruptive, the new product or process will have to overcome major hurdles of becoming accepted as the new way of doing business. Different types of innovation face different obstacles, but the more radical or disruptive an innovation is, the more challenges will accompany its acceptance and implementation. Table I summarizes six major barriers to innovation in transportation based on the findings of five studies that have identified conditions creating barriers to innovation and its implementation in the transportation.

TABLE I Common Barriers to Innovation in Transportation

	Barrier	Description of Barrier
1	**System Diversity and Complexity**	Diverse, decentralized, and multifaceted highway industry. Conflicting public- and private sector incentives (**1**). Fragmentation, disagreement among public works constituencies, and competition among public works categories for scarce resources have combined to constrain innovation (**7**).
2	**Intellectual Property and Procurement Restrictions**	Constraints imposed by public-sector procurement practices (**1**). Public-sector procurement activity is driven by low-bid process based on specifications and procedures established to satisfy the need for open competition and accountability (**7**). Competitive bidding requirements represent a core problem because certain innovations are offered by a single company. Conflict between open public bidding processes and private Intellectual Property (IP) rights can hamper deployment of innovative products (**9**). Excluding evaluation contractors from implementation contracts can limit competition at the deployment stage (**8**).
3	**Risk Aversion**	Low tolerance for risk in the public sector (**1**). Public-sector decision makers work in an environment that does not reward risk taking. If public officials are unfamiliar with the potential of innovative technology or uncertain of its merits, they are reluctant to adopt it (**7**).
4	**Resistance or Inability to Change**	Organizations limit and resist change (**1**). "When optimal resolution of a product or process performance problem demands a very different set of knowledge than a firm has accumulated, it may very well stumble" (**10**). Lack of training and skilled employees prevents technological change (**8**).
5	**Lack of Profit**	Public-sector innovation is not subject to the profit motive that stimulates commercial innovation (**7**). Disruptive technologies are "initially embraced

	Motives	by the least-profitable customers in a market" (**10**). Companies who let customers identify only new products that promise greater profitability and growth "are rarely able to build a case for investing in disruptive technologies until it is too late" (**10**).
6	**Lack of Product Evaluation Criteria**	Difficulty of characterizing and predicting system and component performance of the new innovation (**1**). New product evaluation guidelines are slow to develop and are under-resourced (**8**). Requirements are unclear or not defined (**9**). At Caltrans, it is difficult to get business cases for Information Technology products approved through the extensive and cumbersome Feasibility Study Report process (**8**).

BARRIERS TO INNOVATION AT CALTRANS – THREE CASE STUDIES

Case Selection

The case studies selected here represent innovations that are actually being commercialized and are in different phases of adoption by Caltrans. Each case has a unique set of roadblocks depending on the technology and deployment context. All three cases represent products that have been developed by either Caltrans or partners of Caltrans through the direct involvement of the Caltrans Division of Research and Innovation (DRI).

Although these innovations promised significant return on investment, deployment of each faced numerous and significant challenges that delayed implementation. In each case study, the inventors as well as the researchers, practitioners and engineers involved were interviewed to identify and analyze roadblocks that were encountered. The first case, Sensys, is a compact, self-contained, highly reliable, low cost wireless traffic sensor system that can replace traditional, less reliable, more expensive inductive loops. The second is CA4PRS, a software that simulates highway construction and traffic activities at construction zones and predicts traffic delays associated with each simulation scenario. The most optimal scenarios are then recommended for implementation. The third, Balsi Beam, is a mobile safety steel frame designed to protect highway maintenance workers.

The Balsi Beam and Sensys case studies will document the path to commercialization of both products, but with Balsi Beam being state owned and Sensys being privately owned. The CA4PRS software is also being sold to other states through the University of California, Berkeley. CA4PRS licensing requirements have been a significant hurdle for other state departments of transportation to purchase and use the software.

Research Methodology

Barriers in each of the three cases were identified through two methods. The first is authors' first hand experiences helping develop these innovations. The primary author is the DRI Chief in charge of moving these three innovations forward. The second is one-on-one interviews with the inventors and principle researchers of these innovations. Some end users were also contacted. Project data for each case were collected from project managers for each case, Caltrans project databases, and the literature. Mitigation measures tried to mitigate the barriers are described. Lessons learned are then listed for each case and summarized in the Summary and Conclusions section.

Sensys™ Case Study

Sensys™ is a compact, self-contained, easy-to-install, highly reliable, low cost wireless traffic sensor system that can replace traditional, more expensive inductive loops. The Sensys concept originated at through Partner for Advanced Transit and Highways (PATH) Program, at the University of California, Berkeley through special research program in 2002 dedicated to exploring new ideas. Through DRI, the program provided up to $25,000 for 1-year research proposals strictly intended to test or demonstrate new ideas and concepts.

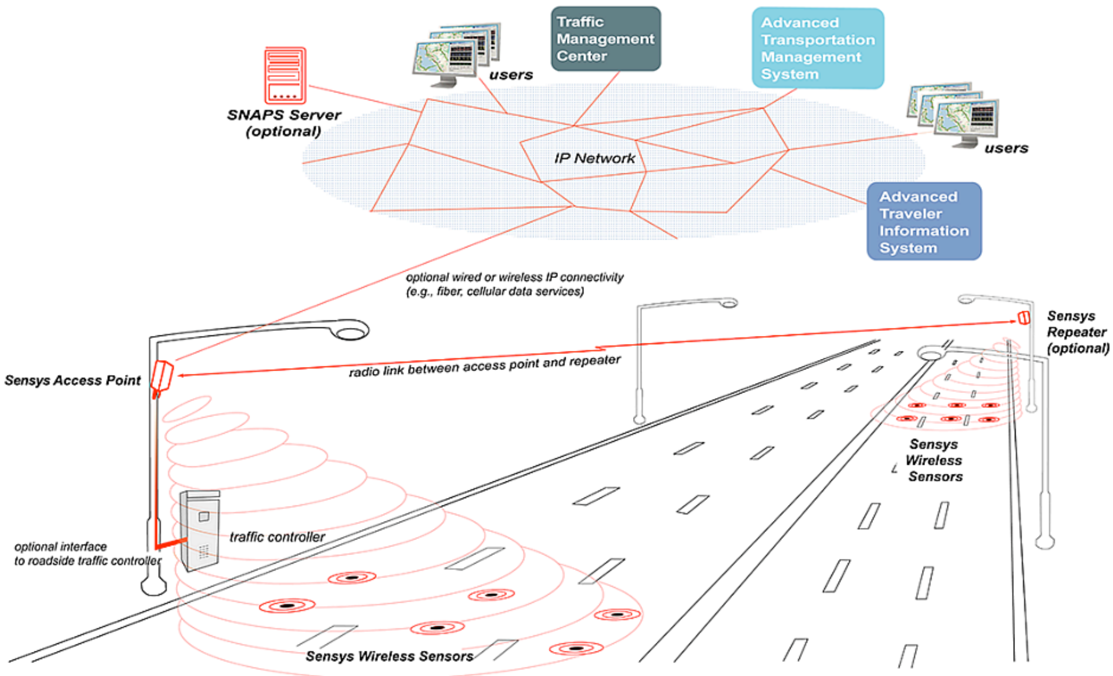
The $25,000 Sensys proposal was to investigate the potential use of a new wireless detector that could collect similar traffic data collected by wired inductive loops that have been in use since 1960. The research proposed to investigate the use of MEMS (micro electro-mechanical systems) acoustic sensors, a prototype of which was developed earlier in the Department of Electrical Engineering and Computer Science at UC Berkeley under a previously DARPA-sponsored project. Researchers proposed to test how well MEMS sensor network would detect traffic in urban streets and parking lots and determine how effectively these sensors can operate in an urban traffic environment, and how much spatial and temporal resolution can be achieved (**11**).

Sensys research proposal was approved and seed money provided by Caltrans allowed the researchers to explore and test the concept within one-year time. During the research, the researcher switched from the initial detection technology (acoustical sensors) to magneto-resistive sensor. They also redesigned the system's protocol to increase communications efficiency and reduce energy consumption (**12**). The first Sensys prototype was ready for testing in 2003.

Based on the promise of this "disruptive" technology, Sensys Networks was incorporated in 2003 by two former UC Berkeley graduates working with the inventor Professor Pravin Varaiya. Venture capital investors initially balked at investing in Sensys because innovations for Government take too long. However, Siemens TTB and ComVentures, venture capital investment companies, were convinced of the potential and provided seed money in 2004-2005. In May 2005, the new detector, code-named VDS240, was announced at the 15th Annual Intelligent Transportation Society of America (ITS America) meeting. Production units were shipped in late 2005 to be considered by potential clients and to be evaluated in pilot projects. Horizon Ventures provided additional seed funding in October 2006 (**13**).

Figure 1 illustrates an operational Sensys Wireless Vehicle Detection System. Magneto-resistive sensors buried in pavement transmit real-time data wirelessly via low-power radio waves to roadside access points that in turn relay data to local or remote receivers. Repeaters may be used to support sensors installed beyond the radio range of access points.

Data needed for local traffic signal control are transmitted via a local roadside traffic controller. Data for remote users such as traffic management centers and/or Internet service providers are transmitted via IP (Internet Protocol) communications over twisted pair, coaxial cable, fiber-optic cable, and cellular data services.



<u>Figure 1.</u> Illustration of Sensys™ Wireless Vehicle Detection System on a freeway.
Source: http://www.sensysnetworks.com/system.html

Two of the barriers to the implementation of the new Sensys system emerged at the testing stage. There was no funding allocated for testing and there were no criteria with which to evaluate its effectiveness.

DRI persuaded decision makers at Caltrans to fund the evaluation through California Center for Innovative Transportation (CCIT). DRI argued that Caltrans must use a more reliable technology like Sensys to collect accurate traffic data that are critical for implementing the Governor's Strategic Growth Plan through the $19.9 billion Transportation Infrastructure Bond approved by California voters in November 2006. Caltrans needed to install 1000-2000 new traffic monitoring stations to fill in the areas where detection was missing.

Between 2006 and 2007, CCIT performed an evaluation of prototype production units at the Berkeley Highway Lab on Interstate 80 to determine the data quality provided by the Sensys detectors. CCIT evaluated three elements: 1) effectiveness of installation procedures, 2) performance of wireless data links, and 3) quality of data collected. Evaluation results showed that Sensys units were easy to install with an average pavement installation time of 10 minutes/unit, that wireless links performed reliably and reported data in a timely manner and that data sets were complete, valid, and accurate.

Sensys™ Roadblocks

Satisfactory evaluation results were not enough to move towards deployment and few new barriers emerged. CCIT selected random chunks of data and used video and an operator to visually count cars and establish true flow count (**12**). Critics argued that all data collected, not only select intervals, should have been verified by comparing visual count of every single vehicle to that of Sensys data. Critics also complained that the performance of Sensys sensors was not tested continuously for periods of 24 hours/day, seven days a week. Moreover, Sensys president noted that: "In the transportation industry, there seems to be skepticism about young companies being able to deliver a good product" especially if they are not based in the Silicon Valley (**15**). "I believe that the transportation industry is skeptical of innovation from young companies - even if they are based in Silicon Valley," he added. Additional testing was performed by Joe Palen of Caltrans DRI to validate Sensys over a 24/7 period using video-sync software to validate the accuracy of Sensys data. This additional testing took over a year to perform due to development of a test process and difficulty of collecting and analyzing the data. Both the CCIT evaluation report (**12**) and Palen's evaluation report (**14)** noted the potential for interference of WiFi and other radio signals for the units. The mere potential for interference of WiFi and other radio signals for the units caused some to reject the system altogether. Few transportation agencies that looked into Sensys had no structured evaluation criteria and only arbitrary decision-making process to decide whether to accept it or not. Finally, to protect their invention, Sensys developers created proprietary hardware and software that, in turn, made it very difficult for state agencies to acquire the system through conventional open bidding process. Table II lists a summary of barriers encountered and mitigating measures used during the development and deployment of Sensys.

TABLE II Summary of Barriers Encountered and Mitigating Measures Used During the Implementation of Sensys™

Barrier	No. in Table I	Mitigating Measure Used by Caltrans DRI
Lack of funding to explore new concepts in complex systems	1	DRI created a small ($25,000) and limited (1-year) research grants to investigate and test new ideas.
Lack of functional requirements, specifications, and evaluation criteria	6	DRI commissioned CCIT to perform an evaluation and performed a supplemental evaluation using comparable criteria.
Lack of provider credibility	3	DRI assured end users that Sensys was a reliable product backed not only by the manufacture but also approved by Caltrans.
Resistance to change and risk aversion	4	Proactive communication was pursued through reports and informal discussions. DRI recruited champions at Caltrans Division of Traffic Operations who sanctioned the additional testing.
Sole-sourcing contracts	2	DRI had relied on use performance-based specifications.

Lessons Learned

Several important lessons were learned in this case. One is that logical criteria must be established in a timely fashion to test the new innovation. Customer-approved key performance indicators must be identified and performance must be measured with reasonable resources. It was learned that, in order to establish credibility, testing performance standards for new products should be as rigorous as or more rigorous than performance standards for existing products.

Using principles of systems engineering, functional requirements should have been specified and used instead of promotional product descriptions. In all cases, a company trying to meet the client's requirements must clearly understand the process for getting the product approved for use by the client (**12**).

Intellectual property (IP) was not an issue with this innovation because the IP was handled through the University of California's IP licensing process. This required a substantial effort by Caltrans to get the approval of the California Department of General Services to allow the University to own the IP developed by the University research.

Overall, this innovation is considered a success story because Sensys was a start-up company that became profitable in three years. Fewer than 10% of all start-up companies have the ability to become profitable in such a short time. Varaiya (**15**) credits a large amount of Sensys success to the excellent communications that took place between the developer and the customer (Caltrans) that included criticism, encouragement, and recommendations of how to make the product better.

The importance of innovation champions was a critical factor for the successful deployment of Sensys. Varaiya (**15**) believes that acceptance of Sensys in California by Caltrans will establish confidence in Sensys and pave the way for other markets to deploy the product.

CA4PRS Case Study

CA4PRS stands for *Construction Analysis for Pavement Rehabilitation Strategies*, a software package that has been developed by the University of California Pavement Research Center (UCPRC) with funding from DRI. This case study focused on roadblocks that surfaced during the deployment of this software. CA4PRS aids engineers and contractors in selecting economical highway rehabilitation strategies that minimize disruptions to drivers and to the surrounding community. It identifies optimal construction management strategies that balance construction schedules with traveler inconvenience while minimizing agency costs by considering "what if" scenarios for variables such as construction time windows, number of lanes to be closed, material selection, and site access for construction vehicles (**16**).

Figure 2 is an illustration of the flowchart of "what if" scenarios. For each scenario, schedule, traffic, and cost are analyzed. Construction plan scenarios that are feasible, accommodate traffic, and cost-effective are chosen.

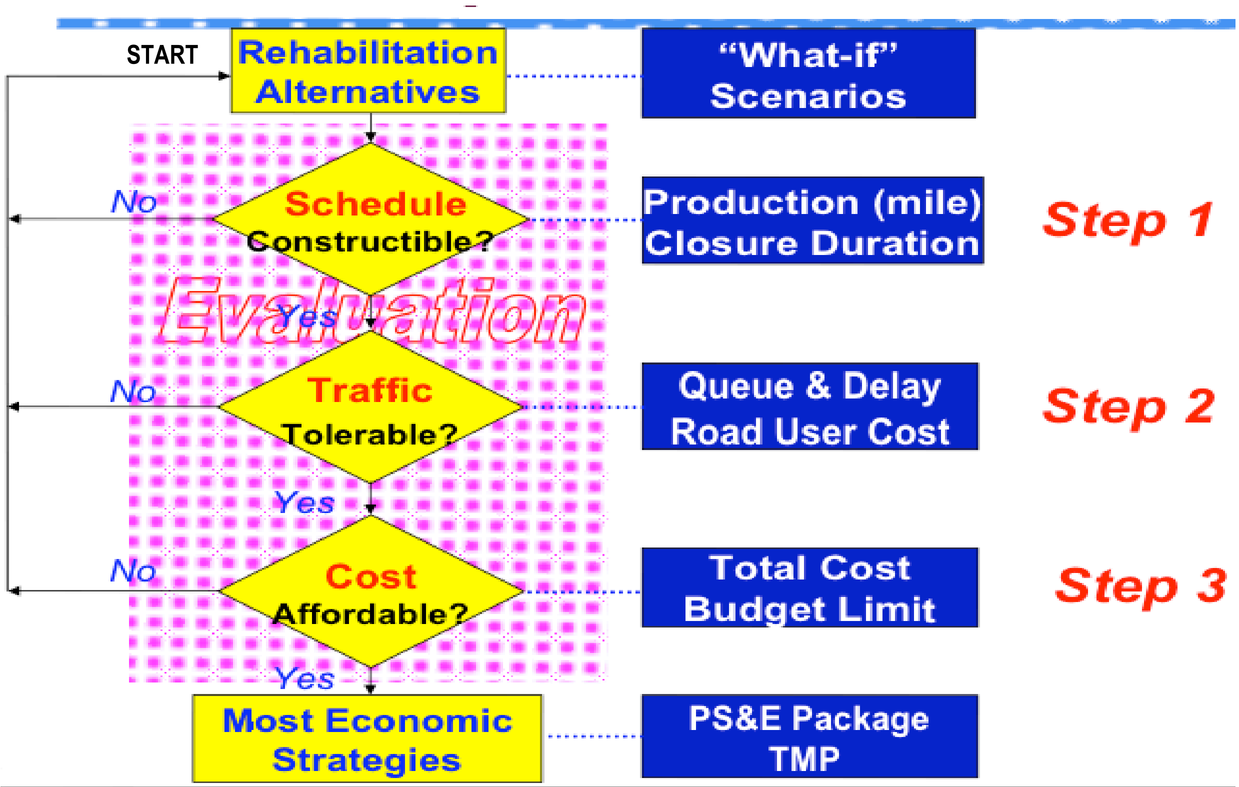


Figure 2. **CA4PRS simulation and evaluation flowchart.**
Source: http://www.dot.ca.gov/newtech/roadway/ca4prs/index.htm

CA4PRS was first tested in 1999 in a construction project along a stretch of Interstate 10 near Pomona east of Los Angeles, California. Data from that project validated CA4PRS simulated production rates and impacts on traffic. Before the work began, contractor's estimate for a 55-hour weekend production rate was 3.5 lane-km. CA4PRS estimate was 2.9 lane-km. Actual performance came to 2.8 lane-km (**17**).

The second major construction project was on Interstate 710 near Long Beach in Southern California in 2002. The original construction plan called for ten 55-hour weekend closures. However, encouraged by an incentive provision of $100,000 for each weekend closure eliminated, the contractor used CA4PRS and finished the job in eight consecutive closures instead of ten and claimed a $200,000 incentive bonus. (**18**).

The third major project was in 2004 along a 4.5 km (2.8 mile) stretch of Interstate 15 near Devore in Southern California. Original construction schedule called for 10-month nighttime-only closures. However, using CA4PRS proposed scenario, this badly damaged concrete stretch was rebuilt in two single-roadbed continuous closures (also called "extended closures") totaling 210 hours, using counter-flow traffic (opposite direction to the main traffic flow) and 24-hour-per-day construction operations (**17**).

CA4PRS Roadblocks

The American Association of State Highway and Transportation Officials Technology Implementation Group in 2006 designated CA4PRS as a "priority technology". Despite this and the fact that CA4PRS proved to be a valuable time and money saving innovation, it had its share of roadblocks. CA4PRs was developed outside of the normal Caltrans Information Technology (CIT) development process using a Transportation Pooled Fund project with the states of Washington, Minnesota, and Texas participating in the pooled fund effort. However, in order for CA4PRS to be accepted and allowed by CIT to become as standard Caltrans software (and for Caltrans users to install it on their PCs), an extensive benefit-cost analysis justifying the acquisition of the software for Caltrans had to be conducted and an extensive and cumbersome Feasibility Study Report (FSR) had to be completed. Developing an FSR for CA4PRS was an extremely time-consuming, unnecessarily complicated, difficult, and frustrating process.

Soon after the CA4PRS FSR was completed and after CA4PRS was incorporated into Caltrans Technology Standards list, a new deployment roadblock emerged. CA4PRS software needs to be installed on each engineer's computer individually. According to CIT protocols, individual installation of software requires the work to be performed by CIT staff. CIT staff was not able to perform the installation work in a timely manner for the many users. As a result, many design and traffic engineers gave up on installing and using CA4PRS altogether.

Marketing of technology is critical for its success because often the information is available, but it requires too much effort to find. Marketing successful results of research by going out to the customers is a proactive approach that Caltrans has used to "push" this technology out to users. Caltrans has learned that producing a report that resides on a Web page or in a library is not an effective way to deploy innovation.

Seeking external (national and international) recognition for innovative research is a strategy that DRI has used to build credibility for CA4PRS within Caltrans at management and staff levels. In 2007, CA4PRS was nominated and earned the International Road Federation Global Road Achievement Award for the Research Category. CA4PRS is also included on the FHWA Priority Market-Ready Technology list. During a recent ceremony with the Director of Caltrans, the question was asked, "Why aren't we using this tool on all of our projects?"

Caltrans had tried but faced challenges making CA4PRS a national tool. Recently, Caltrans faced roadblocks in trying to share CA4PRS with other states that were interested in improving how they evaluate construction closures and pavement rehabilitation strategies. To alleviate the financial burden that other states may have in acquiring CA4PRS, Caltrans took the initiative and has been working with FHWA to assist other state DoTs in the purchase of the licensing rights through the *Highways for Life Program.* The University of California has established a cost of $150,000 for all states to be allowed exclusive rights to use CA4PRS. The current cost for a state to purchase a CA4PRS enterprise license is $5,000, which is relatively inexpensive. Nonetheless, many states were unable to get the approval from their own IT departments to acquire the software for reasons similar to the Caltrans experience. On the marketing side, Caltrans has hosted national videoconferences to expose the other states to the potential benefits of CA4PRS.

Finally, lack of training is an impediment to using CA4PRS. Therefore, Caltrans, in cooperation with University of California at Berkeley, has established a training curriculum. Over 700 people have been trained to use CA4PRS so far. This includes approximately 100 users from other states.

Table III lists a summary of barriers encountered and mitigating measures used during the development and deployment of CA4PRS.

TABLE III Summary of Barriers Encountered and Mitigating Measures Used During the Implementation of CA4PRS

Barrier	No. in Table I	Mitigating Measure Used by Caltrans DRI
Lack of product evaluation approval process for IT related technologies	6	DRI had to rely on traditional FSR
Resistance to change, breakdown in bottom-up communications	4	Communication and marketing of case study results and continuing to work with and train the customers. Briefings were provided to key decision-makers to support innovation.
Risk aversion	3	DRI used CA4PRS in pilot studies that demonstrated its success. DRI won credibility for CA4PRS through winning national and international recognition. DRI used champions at staff and management levels throughout all stages of deployment.
Lack of profit motive	5	Construction and traveler delay cost and savings were documented. Establishing the savings in support costs is very important to Capital Outlay Support managers, and this information helped make decisions that supported the use of CA4PRS.
Difficulty in sharing innovations with other states	1, 4	CA4PRS has been demonstrated at numerous AASSHO forums such as the Standing Committee on Highways and Research Advisory Committee. DRI worked with FHWA to provide national videoconferences to other DOTs. DRI Established a curriculum and trained approximately 700 users of the software in and outside California. DRI played leadership role in securing federal funding via *Highways for Life Program* to help other states purchase CA4PRS.

Lessons Learned

The most important lesson learned is to be flexible and resourceful. Although the FSR was difficult to do, DRI used it to as a way to document the benefits and costs of CA4PRS. DRI managed to overcome the license cost issue by using *Highways for Life Program* to help other states purchase CA4PRS. Finally, it was learned that without a curriculum and training plan, this innovation would not be used.

Balsi Beam Case Study

Protecting the safety of construction and maintenance field crews and motorists on roadways has long been a top priority for Caltrans. More than 40,000 people are injured each year in the United States as a result of motor vehicle crashes in work zones. Fatalities from work zone crashes have increased by more than 50 percent between 1999 and 2004 **(19)**. In 2004, the cost of a fatality was estimated to be $1,011,000. The cost of a critical injury was estimated to be $858,000 (**20**).

Balsi Beam is an innovative mobile work zone protection system that was envisioned by Caltrans Division of Maintenance staff. The Balsi Beam is named after Mark Balsi, a Caltrans landscape worker who suffered major injuries when he was working along Route I-280 in Santa Clara County, California in January 2001.

The Balsi Beam was designed, built by Caltrans Division of Equipment, and is utilized by the Caltrans district bridge crews to protect maintenance workers performing tasks on the highway. The Balsi Beam would not be deployed today without the support of the Bridge Crew from Caltrans District 3 in Marysville, CA.

The Balsi Beam system is basically a tractor-trailer combination, with the specialized trailer that extends into a thirty-foot long work space in between the rear axles and tractor, shielded on one side with two steel beams" (**21**). The trailer provides an extendable steel barrier to protect workers on traffic-exposed flank of a work zone.

Figure 3 shows three snapshots of the system. Each side of the trailer consists of high-strength steel box beams that can be extended an additional 3.6 m (12 ft). Using hydraulic power, each beam can rotate 180 degrees to either side (left or right), depending on which side of the road protection is needed. The trailer extends to provide a total of 9.1-m (30-ft) secure work zone **(19).**

<u>Figure 3.</u> Three snapshot pictures of Balsi Beam. [1] In use by Caltrans crew for small spot median barrier repair I-80, Colfax, CA, [2] During 180° vertical rotation, and [3] Double-stacked on right side at a Caltrans maintenance yard.

Balsi Beam Roadblocks

One of the barriers to using this innovation was customers' uncertainty about the effectiveness of Balsi Beam, essentially getting maintenance crews to use a new product like the Balsi Beam. In the opinion of the inventor, Balsi Beam is not ready for any national deployment because it is still a prototype. In her opinion, Balsi Beam will prove effective when it has been actually hit and has saved lives **(22).**

Another barrier to spreading its use has been customers' lack of familiarity with its capabilities. The complex logistics of introducing a new tool into their existing processes at Caltrans made the deployment of this innovation difficult.

Balsi Beam has strong business (and safety) case but documenting such an innovation case for commercialization was a new process for Caltrans. Documenting the business case for the Balsi Beam was essential for getting additional resources to purchase additional units through the Budget Change Proposal process at Caltrans. Documenting the business case not only yielded a solid and presentable business case, but also during the process itself, stronger links were established between champions at all levels for this innovative system from regular highway maintenance workers to the Chief for the Division of Maintenance at Caltrans, District Director for District 3 (in Sacramento), and Caltrans Chief Deputy Director. This made the case stronger to implement the Balsi Beam.

A consultant was hired to help DRI establish a process to sell the licenses to vendors to produce units for other states. Two goals of commercializing the Balsi Beam were to improve the product design and to reduce the costs to produce the units.

A major obstacle for getting the approval to deploy additional Balsi Beam units has been its high capital cost. The capital cost of the original prototype unit was $257,000. Capital cost for a new, fully operational unit is estimated to be as high as $600,000-700,000. Increases in price of steel, complex system requirements, and potential liabilities are behind the cost increases. High capital cost has become a barrier to deploying Balsi Beam at Caltrans and to marketing it to other state DoTs. Concerned about its high cost, the California Department of Finance asked Caltrans to evaluate other less expensive mobile work zone protection devices. Caltrans will purchase an additional three Balsi Beams units and three ArmorGuard™ units. This research suggests that one way to reduce the high capital cost is to optimize Balsi Beam design and its manufacturing processes. Another way is to mass-produce the system spreading the fixed manufacturing costs over larger number of units by marketing it to other state agencies and overseas.

The patent and resulting Intellectual Property for the Balsi Beam is an important discussion point that relates to implementing innovation. CCIT conducted a study to analyze problems related to intellectual property and licensing of the Balsi Beam and concluded that Caltrans may have hampered the marketing of Balsi Beam by patenting it (**12**). Almost all states have competitive bidding requirements to assure that they get the lowest price for the products they buy. Same study concluded that if a patent or licensed product requires exclusive, non-competitive bid, government entities might not be able to purchase the product because of the restrictions placed on non-competitive bids.

One way for Caltrans to share this innovation with other states would have been to “gift” the license to other states or venders. However, California law prohibits Caltrans from doing so. Article XVI § 6 of California Constitution prohibits any public agency from making “any gift of any public money or thing of value to any individual, municipal or other corporation whatever” (**23**). As a result, DRI has developed licenses to allow other states to purchase the right to use Balsi Beam through license agreements.

Uncertainty in determining a market value for Balsi Beam has been a financial stumbling block facing the implementation of this innovation. A license agreement with the State of New York was held up for about one year waiting for the license to be developed and approved. In an effort to solve this problem, DRI commissioned CCIT in 2007 to conduct a study to estimate a market value for Balsi Beam license. CCIT study concluded that a fair market value for the license would be $2.6 million. The study further assumed that there is demand for 136 units that could be marketed eventually. Thus, the license cost per unit would $19,000 per unit (**12**). Fair market value is critical for establishing that Caltrans gets a reasonable compensation for the Intellectual Property and for complying with the State Constitution that prevents gifts of public resources.

Table IV lists a summary of barriers encountered and mitigating measures used during the development and deployment of the Balsi Beam System.

TABLE IV Summary of Barriers Encountered and Mitigating Measures Used During the Implementation of Balsi Beam System

Barrier	No. in Table I	Mitigating Measure Used by Caltrans DRI
Unfamiliarity of customers with Balsi Beam	3, 4	Demonstrations by the crew using the Balsi Beam helped get the word out to the maintenance community. Training that is well developed and supported. Having champions at all levels to support the Balsi Beam is critical for the success of implementing this innovation.
Lack of evaluation criteria and uncertainty about its efficacy	6	Establishing the business case using worker safety data and in-field evaluations overcomes the institutional issues. DRI commissioned CCIT to perform an evaluation. DRI funded research at University of California at Davis to perform benefit-cost and risk evaluation study.
High capital cost of the new innovative product	5	DRI is using commercialization to reduce capital cost by improving the design and optimizing manufacturing procedures as well as mass-producing the units to domestic and international customers.
Balsi Beam patent restricted competitive bidding at other state agencies, California law prohibited sharing (gifting) this technology with other states	2	DRI is developing licenses to grant other states right to use Balsi Beam. DRI will be issuing an RFP to sell Balsi Beam license to multiple qualified vendors.
Uncertainty in evaluating Balsi Beam market value	6	DRI conducted a study and estimated a fair market value for Balsi Beam

Lessons Learned

This case study illustrates the importance of creating champions at all levels of the organization from the crew level to top management. Getting to this stage in the deployment of innovation has taken considerable time and dedication on part of Caltrans and DRI champions at all levels in the organization.

IP was a significant issue with the deployment of the Balsi Beam. It is different than the other two case studies because Caltrans owns the patent for the Balsi Beam. Developing standard license agreements for use by other states and providing a market assessment were effective in overcoming the IP roadblocks. Caltrans is very close to issuing RFP to sell the licenses to vendors who will allow other potential customers to purchase Balsi Beam through commercial channels. Commercialization should optimize Balsi Beam design and manufacturing process and lower production cost. Mass production is also expected to lower unit cost.

Finally, marketing the Balsi Beam across the country has helped to gain credibility within California by proving that this technology is unique for the purpose of obtaining resources to purchase additional units. In June 2004, Caltrans sent the Balsi Beam across the nation on a multi-state tour with the final destination being a demonstration for the AASHTO Standing Committee on Maintenance. Caltrans also marketed the Balsi Beam through many FHWA publications and by adding the Balsi Beam to the AASHTO Technology Implementation Group (TIG).

SUMMARY AND CONCLUSIONS

This paper examined Caltrans experience in three recent showcase innovations developed at Caltrans DRI. Although these innovations promised a significant return on investment, their deployment faced numerous challenges. For each case, inventors and engineers were interviewed to identify and analyze roadblocks that were encountered.

The main finding of this paper is that in these three cases in particular, and in similar cases in general, deployment of innovation faces roadblocks because transportation projects are complex, multifaceted, inter-jurisdictional with many players having different interests; multiple layers of decision making sometimes lacking logic; public sector procurement driven by competitive multiple low-bid processes often infringing on intellectual property rights of sole providers; risk aversive governments; resistance to change, and even if change is accepted, it often requires passing new laws. Lessons learned about these barriers and mitigation measures that worked successfully in each case are summarized and analyzed in this paper. Lessons learned encompass the need to be flexible and resourceful, need to establish criteria for evaluating new innovations not yet market-tested, commercialize to minimize implementation costs, and ensure users receive adequate training. Forward-thinking innovation champions at all levels will be needed and they have helped keep Caltrans on the forefront of technological innovation nationally and worldwide.

To mitigate roadblocks, this paper recommends following systems engineering process to for developing and implementing innovations. Such a process will ensure improving communications between researchers, developers, operators, and decision makers. Finally, this paper recommends to occasionally allowing some non-competitive biding preserving intellectual property rights.

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